THE GAS TURBINE

By A. J. ZERNIN

War has always been a busy time for inventors, and in modern times the battle of minds working in laboratories and workshops has risen to an importance equal, if not superior, to that of the battles fought by the soldiers in the front lines. Having realized this, every belligerent state is lavishing its financial support upon every experiment and test that may, in one way or another, contribute to the total war effort. Although most of the inventions and technical improvements are at present directed toward purposes of destruction, some of them will, in the end, be of great benefit to mankind as a whole. One of these is the jet-propulsion plane described in the last issue, another the gas turbine.

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THE gas turbine is the youngest member of the family of thermal prime movers. It put in its first appearance some ten years ago, after its various experimental models had passed through thirty years of development, years filled with hard work and not always free of disappointment. The problem of the gas turbine has been studied by many inventors in various countries and has been handled in different ways.

The name "gas turbine" is somewhat misleading, as the turbine is only a part, although an essential one, of the total heat engine. It is true that what enters the turbine part of the power plant is actually in gas form; but this does not necessitate the gas-turbine plant being fed with a gas fuel. This new type of prime mover can be operated with either solid, liquid, or gaseous fuel.

In order to convert the fuel—whether coal dust, oil, natural gas, blast-furnace gas, producer gas, etc.—into that gaseous state in which it can be utilized by the turbine part, a heat generator is required, forming the second essential device of the prime mover. According to the type of the gas turbine, this device consists of either an explosion chamber or a combustion chamber. The third principal part of the gas turbine, likewise absolutely indispensable for each system, is a compressing device for the combustion air and, when gas fuel is used, also for the gas. In addition to these three essential parts, there are such other equipments as fuel feeders, speed and load regulators (governors), heat recoverers, coolers, etc., which are also indispensable but of a secondary nature and which are to be found in a similar form with other heat engines.

There are three basic types of gas turbine in existence, each with its individual merits. However, in order not to burden this article with too many engineering details, we shall consider only the combustion turbine, which is not only the simplest of the three types but has also reached the highest degree of perfection and can boast of the largest number of engines already in operation.

The accompanying diagram shows the arrangement of the combustion turbine and its parts and illustrates its working method. Through the air intake, the combustion air enters the rotary air compressor at atmospheric pressure. After having been compressed, it passes on to the combustion chamber, where the fuel—gas, oil, or coal dust—is injected in a continuous stream by means of a nozzle. Here the combustion heat of the burning fuel is transferred to the air which, for reasons which we shall explain later, is blown in in a quantity several times in excess of that required for complete combustion.

In the turbine itself, the expanding gas drives a rotor equipped with a series of blades against which the gas current is guided by a series of vanes fixed to a stator. Thus there is no difference here in comparison to the steam turbine. Indeed, the simplest form of a turbine is a windmill, which also produces power by transforming the energy contained in a stream of gas (air) into mechanical energy. After leaving the turbine, the gas escapes by the discharge pipe; but as it still contains a considerable amount of heat, the exhaust passes through a preheater, where the air entering the compressor is preheated, thereby reducing the fuel consumption of the unit. In cases where simplicity, a minimum of space, and light weight are given first consideration, gas turbine plants may dispense with this air preheater.

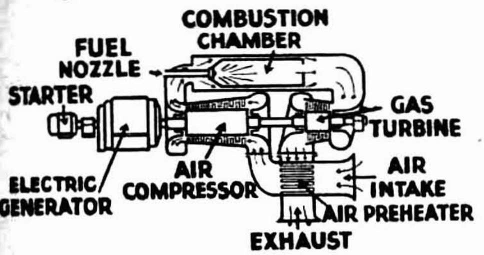

Diagram of the Combustion Turbine

As may be judged from the diagram, the design of the gas turbine of this particular type is simple compared to that of steam, Diesel, or other combustion engines. The principal moving parts of the combustion turbine are the revolving rotors of the turbine and of the compressor. There are, of course, auxiliary devices such as the automatic governor, which controls the admission of fuel and regulates the speed at varying loads; the feed device for the fuel; and a starter. But these mean nothing in comparison to all the many parts and auxiliaries of a complete steam plant or of a Diesel or other reciprocating combustion engine of the same capacity.

To set the engine in motion, an independent source of energy has to effect the initial compression of the combustion air. For this reason, the diagram also shows the starter, in most cases probably an electric motor which takes its power from the mains. In the case of independent and isolated engines, like locomotives, aircraft and other engines, other means must be employed for the starting device, which may raise a problem where light weight is essential.

Like the steam turbine, the gas turbine is a high-speed prime mover and therefore suited for driving rotary machines. Electric generators, centrifugal pumps, rotary air and gas compressors, and propellers of 3,000 revolutions per minute or more, are the field in which gas turbines may be employed with advantage. Other equipment to be driven may necessitate the use of a reduction gear, but the simplicity of the gas turbine will cause designers to consider the application of this new prime mover even under such circumstances.

The first gas turbine of the type described was built by Lemale and Armengaud in 1904 but, owing to the technical inadequacies of the time, this turbine was practically only able to drive its own air compressor. In 1926, Dr. Aurel Stodola, an outstanding Swiss authority in the field of turbine research, proved mathematically that this must always be the case unless some wizard were able to construct a far more efficient air compressor. Ten years later, Dr. Stodola himself was able to carry out impressive tests with the first successful experimental gas turbine. In the intervening years, discoveries had been made in two entirely separate industries which provided the clue to the solution of the problem. On the one hand, the metallurgical industry produced alloys to withstand great heat and corrosion from burning gases. On the other, aircraft research, in its effort to discover the best profiles for airplane wings and propeller blades, laid down principles which aided several of Dr. Stodola's assistants in constructing more efficient compressor and turbine blades.

Until recently there was no material from which the turbine blades, vanes, and other guide apparatus could be constructed that could, for any extended period, withstand the constant contact with gases at a temperature exceeding 600° centigrade. On the other hand, the combustion of the various fuels raises the temperature by from 1600° to 2400° centigrade; and, as the combustion air forced into the combustion chamber is usually already preheated, gas temperatures of from 2000° to 2500° might easily be obtained for the operation of the turbine. In order to reduce this temperature, the large excessive quantity of compressed air, which we mentioned before, must be blown into the combustion chamber. From the point of view of thermal efficiency—i.e., converting as much heat energy contained in the hot gases as possible into mechanical energy—nothing would be more desirable than to operate with the hottest gas, and it is a pity that, on account of the inadequacy of the construction material, the combustion gas has to be diluted by so great an excess of air that its temperature is reduced to 600° centigrade. This applies to all combustion turbines hitherto installed. According to reports reaching us from America, new turbines are being constructed to be driven at a temperature of 800° centigrade, an improvement which has apparently been made possible through the discovery of new alloys used in the construction of the turbine blades.

The turbo-compressor of Dr. Sanford A. Moss, thanks to which planes can fly at an altitude of 11 kilometers above the surface of the earth, is a turbine driven by the exhaust gases of the aircraft engines, and its blades have to withstand a heat of up to 1,000° centigrade. The research work in connection with this particular compressor gave the turbine constructors many valuable hints. But it did not wholly solve their problem. The turbo-compressor does not have to withstand the terrific heat for more than a few hours at a time, whereas a gas turbine for industrial purposes or ships has to run continuously for weeks on end.

Owing to the low temperature at which the gas enters the turbine, the thermal efficiency of the gas turbine, at least of the type we have described, is comparatively low and amounts to no more than 18 to 20 per cent. Preheating of the combustion air by the turbine exhaust raises the efficiency to from 22 to 25 per cent, while additional devices may raise it to as much as 30 per cent, but this only at the expense of simplicity. In comparison to the modern Diesel engine, these figures are not impressive, as no Diesel engine of 1,000 hp or more would be regarded as satisfactory unless at least 37 per cent of the fuel heat is converted into mechanical energy. However, we must bear in mind that there is also a commercial efficiency which makes it possible for a gas turbine utilizing only 18 per cent of the fuel heat to compete with a high-grade Diesel engine of twice the thermal efficiency. For, aside from other factors, gas turbines can be run on bunker oil, which costs about half as much as does the oil required for the more delicate Diesel engine. Furthermore, we must not lose sight of the fact that gas turbines are still in their infancy and will improve with every progress in temperature effected.

After more than thirty years of development in the research departments of several manufacturing concerns, which went on entirely unnoticed by the general public, the gas turbine was presented for the first time to the engineering and industrial world at the Swiss National Exhibition in Zürich in 1939. This turbine set was designed and built by Brown, Boveri & Co., Ltd., a Swiss firm famous also for their improvement of the steam turbine. Previous to that, a single gas-turbine set had been operated for approximately three years in the United States, but its existence was hardly known. The sensation caused by the turbine exhibited at Zürich was the more complete as it was not a small trial set specially built for the exhibition: it had a capacity of no less than 4,000 kilowatts (6,000 hp). Even in our days of gigantic figures, the set cannot be considered a small one. It had been ordered by the Municipality of Neuchâtel, and after the termination of the exhibition it was erected somewhere underground in that town so as to be out of the range of bombs. This set being intended to serve only in case of emergency, it was not provided with a preheater; and it is noteworthy that, in order to produce an effective load of 4,000 kilowatts, the turbine power amounts to 16,000 kilowatts, 12,000 kilowatts being absorbed by the air compressor.

Since then, quite a number of gas turbines of the same system have been built by various manufacturers, the United States leading with gas turbines running on cheap fuel oil, for which conditions in America are more favorable than in most European countries.

There is one more point which we must touch upon since it will have a great bearing on the future employment of the gas turbine: it requires practically no water for its operation, in contrast to all steam plants, Diesel engines, and other combustion engines. Hence the gas turbine is very suited for hot, dry countries, and for replacing such engines which, like steam locomotives, depend on water and have to carry the water in their tanks or in a separate tender for a working period of two or three hours. Since 1941 a trial locomotive driven by a gas turbine-generator set has been operated by the Swiss Federal Railway Administration. Records are not at hand, but there is no reason to doubt that it is a success.

The thermal process of the gas turbine completely excludes the use of water, with the exception that one or the other inventor may have used water for reducing the temperature of the combustion gas. But the cooling effect of water can be replaced by other means. The possibility of doing entirely without water seems to fit the gas turbine particularly well for use as the propelling engine for aircraft. It is only a matter of time before the gas turbine in its simplest form is developed to so small a size and weight and yet to so high an efficiency that it will be able to compete with the combustion engines now solely employed for this purpose. It is pretty certain that plans and designs of airplanes with a gas-turbine drive have been drawn up and calculated; but it is more than doubtful whether any such scheme has already materialized. There is still more than one problem to be solved, and the reliability of the gas turbine depends to a great extent on the durability and other qualities of the metals used in the construction of the engine.

It can be safely predicted, however, that these problems will be solved sooner or later, and that this newest of prime movers is facing a great future.

GERMANY'S TRADE IN EUROPE

Germany's foreign trade during five years of war is the subject of this article, which was telegraphed to us from Berlin.

THE restraint imposed by the war upon the publication of German foreign-trade figures has led to a plethora of rumors and statements regarding Germany's trade relations with the rest of Europe. The fifth anniversary of the outbreak of the war seems an opportune time to present a picture of the actual course taken by Germany's foreign trade. Let us begin with the figures themselves.

Without the Ostmark (former Austria) they were as follows:

Year	Imports	Exports
	(in billion	*Reichsmark)*
1938	5.4	5.2
1939	4.8	5.2
1940	5.0	4.9
1941	6.9	6.8
1942	8.7	7.6
1943	8.3	8.6

These few figures speak their own language. The interruption of connections with overseas resulting from the outbreak of war led at first to a slight decrease in foreign trade. This decrease was, however, soon made up for by directing the trade that formerly went overseas to the European continent. As time went on, Germany succeeded in considerably increasing the economic ties with the friendly and neutral countries of Europe in spite of the war. The many years of preliminary work put into the trade with southeastern Europe were particularly fruitful. The growth in trade continued without interruption, so that the figures for 1943 for imports as well as for exports exceed the prewar figures by 50 per cent.

The figures quoted refer to actual trade only. Supplies of war material to allied and friendly countries are only included when such supplies were delivered within the compass of mutual trade agreements. On the other hand, the large supplies of arms and war materials delivered by Germany in the form of military aid to her allies are not included in foreign-trade statistics. This aid to her allies represents several times the value of the material actually bought and must be regarded as considerable additional exports on the part of Germany.

The increase of Germany's foreign trade is not diminished if one takes into account the rising prices among her partners in trade. For although the wholesale-price index in a number of countries on the Continent has risen by 100 per cent or more since the beginning of the war, Germany herself with her controlled economics forms a stable island in the sphere of prices. Moreover, Germany has made long-term reciprocal price agreements with most of her trade partners, so that the quantity and value of the trade with Germany is often hardly affected by price fluctuations. Hence German exports have risen during the war in quantity too.

BALANCED FOREIGN TRADE

The above figures show that, thanks to Germany's unbroken export strength, German foreign trade could be kept more or less balanced throughout the years of war. Neither in the case of imports nor of exports was there any considerable or continued surplus. The only exception is to be found in 1942, when there was an import surplus